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A SYSTEMS ANALYSIS OF WATER QUALITY SURVEY DESIGN.

~~FINAL REPORT~~

APPENDIX IV.

DOCUMENTATION

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Roger Smith

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A SYSTEMS ANALYSIS OF WATER QUALITY SURVEY DESIGN

Documentation of the Treatment
System and Indicator Models
User's Guide
Appendix IV

Authors: Dr. T.M. Keinath, Mr. Roger Smith

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is the final report of a three year project titled, "A Systems Analysis of Water Quality Survey Design."

In this project a study was made of water quality surveys conducted by the United States Army Environmental Hygiene Agency (AEHA). Mainly data and reports from studies of Army Ammunition Plants (AAP) were used.

The focus of this project was the development of computer aided procedures which would assure efficient use of manpower and equipment and assure that the measurements taken give a reasonalbe representation of the system. Planning the

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survey, conducting the survey and reporting on the survey were included in the study.

The site modeling program models the manufacturing processes which contribute pollutants to the system, models the sewer system, and models the treatment system including acid or caustic neutralization, settling ponds, and domestic treatment. The inputs to the model are the production levels of the manufacturing processes and the outputs are the predicted pollutant measurement values at each possible measure point in the system.

The resource matching program accepts data defining proposed measurements and matches these against the available time, manpower, and equipment. The output lists the pollutant to be measured at each measure point, the total commitment of time for each analyst and for each piece of equipment. Note is made of any overcommitment of manpower or equipment.

The model refinement or updating program accepts measurements taken during a preliminary survey or during a regular survey and computes suggested new parameters for the process models.

The indicator model program evaluates the performance of sanitary treatment facilities.

The program uses design data, data from the operating log and/or data generated during the survey and computes key operational characteristics. Comparing these with desirable values as cited in design books and manuals will give the survey planner insight into the operation of the system and suggest the need for more survey measurements or the need for changes in operation.

A system was developed for automatic instrumentation of pH, conductivity, and other parameters which use strip charp recordings. Interface hardware was selected and purchased and interface software was developed for direct connection to a digital computer.

A data handling system was developed for use during and after the survey. A PDP8-OS/8 and peripheral equipment was purchased. Software was developed to perform data handling functions and to direct the user in application of the software. The program accepts raw data from the analytical chemist and performs data conversions, transcriptions, and data logging functions. Output is available in several forms as may be needed for various reports during and at the end of the survey.

Recommendations are: the survey planner should obtain sufficient data in a proliminary survey to model and analyze the site; measurements should be automated to the maximum extent possible; data handling should be delegated to the computer when the operations are well defined and repetitive. The programs, software and hardware included here will assist the survey planner in following these recommendations and design a more effective survey.

ABSTRACT

The U.S. Army Environmental Hygiene Agency's Sanitary Engineer is tasked with making decisions in a wide variety of water and wastewater treatment areas. To assist him in two of these areas, this project was undertaken with an objective of developing some computer tools with the engineer in mind.

Estimation of a wastewater treatment plant's capability to cope with an increased load due to a post's expansion is the first area. Given the approximate character of the wastewater resulting from a post's expansion, a steady-state model of the treatment process is used to predict the character of the treatment plant's effluent. Some guidance is thus provided to to the engineer in determining the present treatment scheme's ability to provide adequate treatment after expansion.

The other area in which aid is provided is in the direction and analysis of the water quality engineering special study or "survey". Utilizing design and operational data, a computer model evaluates the operational characteristics of the system. Evaluation may be accomplished with operational data available before the survey and with the data generated by the survey. Operational characteristics calculated are then used by the engineer to evaluate the system's operational condition and to then plan and conduct the survey.

a

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wastewater plant serving the installation will experience fluctuations in loading. In addition to these changes in personnel strength, many other adjustments to the operation of the post can have dramatic effects on the loading of the wastewater treatment plant.

Projecting the effect of such new loadings on a wastewater treatment facility, the sanitary engineer must make decisions as to what physical or operational changes may be required to ensure continued satisfactory plant performance. Estimates of the new loading produced by the population or other changes can be made by the engineer using one of the several methods available in the sanitary engineering literature. An estimate of the future loadings in itself, nonetheless, does not establish the plant's ability to perform satisfactorily under the new loading. The new loading estimate, however, can be used as an input to a computer model of the treatment plant to predict the plant's future performance. Such predictions can be employed by the sanitary engineer in formulating a plan of action to meet future requirements. The model will not give exact predictions of the plant effluent. If the engineer is cognizant of this fact, however, the model will serve as a valuable aid in the decision making process.

The TSM simulates two basic types of treatment systems: those employing either (1) a trickling filter, or (2) an activated sludge system. These two types were chosen because of their prevalent use at U.S. Army installations.

Indicator Model

Analysis of the operation of wastewater treatment plants is a necessity

when increased loadings are expected. Of equal importance is the surveillance and evaluation of a plant's routine operations. Subsequent recommendations regarding process modifications ensure continued satisfactory performance. Consequently, a detailed examination of the system's operational condition is periodically required. This is accomplished by the sanitary engineer through the water quality engineering special study or "survey".

In preparation for a survey, the sanitary engineer or "survey officer" must decide on the protocol for the survey, that is, what water quality parameters are of most interest and where in the system do they need to be determined. This is, of course, predicated on what information is needed to describe the operational state of the system. Models have been developed by others for this purpose. In particular, there are the Process, Topology, and Resource Matching Models developed by the Clemson University Department of Electrical and Computer Engineering. One feature of the Topology model is the provision allowing the survey officer to flag for measurement during the survey, any particular water quality parameter at any point in the system. Flaging in this manner usually is done when the survey officer "feels" a particular parameter may have a significant effect upon the overall operational state of the system.

A preliminary evaluation of the process variables of a treatment plant will provide an initial estimate of its operational state. These process variables, such as weir overflow rates and process loading intensity, are functions of the design and operation of the treatment plant and the character of the wastewater. Thus, a preliminary evaluation of the process

variables will indicate possible areas where stress on the plant exists. The survey officer then determines whether certain key parameters should be flaged and whether measurements within the wastewater treatment plant should be made during the survey.

After completion of the survey, the survey officer must analyze the data collected. This analysis results in the final determination of the treatment plant's operational condition and forms a basis for the survey officer's recommendations to improve treatment plant performance. Again, evaluation of the process variables, this time using the data generated by the survey, will assist the survey officer in determining the plant's operational condition. These variables will indicate areas where design or operational inadequacies exist which may be the cause of unsatisfactory plant performance. Trouble spots in the system can, therefore, be pinpointed. Also, the survey officer can determine, through analysis of the process variables, what remedial action will likely improve plant performance.

The Indicator Model was developed to evaluate these process variables for two types of wastewater treatment systems: trickling filter and activated sludge type of plants. The model can be used to compute the process variables utilizing preliminary operational data that is available prior to the inception of the survey or the operations data generated during the survey.

II TREATMENT SYSTEM MODEL

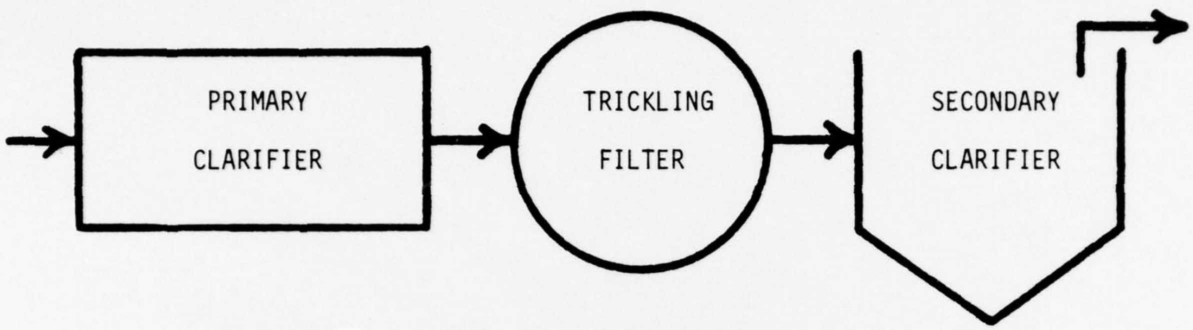
Introduction

A wide variety of computer models have been developed to simulate different wastewater treatment systems. Both steady state and dynamic models have been proposed. While the steady state model does not represent the transient operation of a process and, as such, is generally more simplistic than the dynamic model, it does give an estimate of a process' long-term performance. Since this long-term estimate is what the model is intended to provide, the steady state approach has been used in this development. To quote Andrews [12]:

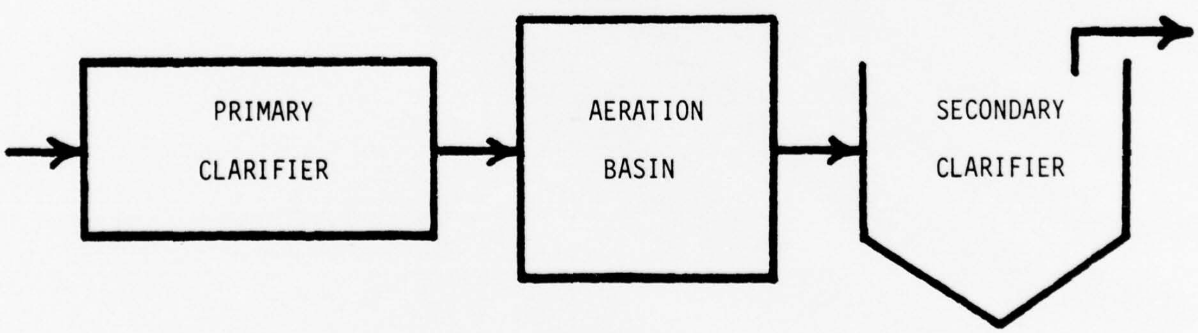
> ...the simplest possible expression should be used. The purposes for which the model is to be used must be defined so that one can be developed which is adequate for the intended use. Mathematical elegance should be secondary and it should be remembered that a model which is too complex may be subject to either misuse or disuse.

Model Formulation

Actually, the overall model which has been developed is a combination of several steady state process models. All the unit processes that are included in the system have been modeled and linked one to another. These include: primary clarification, secondary clarification, the trickling filter, and the activated sludge process. As mentioned before, these unit processes are grouped into two basic treatment trains, one incorporating the trickling filter while the other includes the activated sludge process (see Figure 1).



a. TRICKLING FILTER TRAIN



b. ACTIVATED SLUDGE TRAIN

Figure 1: BASIC TREATMENT TRAINS

Complex interactions between unit processes are not explicitly considered in the formulation of the model. Again, this is not necessary for the intended use of this treatment system model. A more detailed explanation of these complex interactions may be found in the sections dealing with the two treatment trains.

Water Quality Evaluation

Trickling filter and activated sludge systems are both biological processes, *i.e.*, they employ microorganisms to assimilate and metabolize the pollutants in the wastewater. As such, these two systems can only be used to treat biodegradable wastes such as "domestic" wastes and certain types of industrial wastes. To establish the quality of these wastes, a number of water quality parameters have been used in the past.

Four such parameters are most commonly used by sanitary engineers, not only to indicate the wastewater quality, but also to determine the amount of treatment accorded the wastewater by the treatment system. These parameters are as follows: 1) five-day biochemical oxygen demand (BOD_5); 2) suspended solids (SS); 3) ammonia; and 4) nitrates. Given the influent levels of these four water quality parameters and the influent flow rate, the model predicts their respective concentrations in the effluent of a treatment plant.

Performance of each unit process which is incorporated in the treatment train is described by a mathematical expression. The expression is used to calculate the values of the water quality parameters in the effluent of the process. These values then become the input to the next unit process in the

treatment train. The output conditions calculated for the last unit process in the treatment train become the plant's effluent conditions.

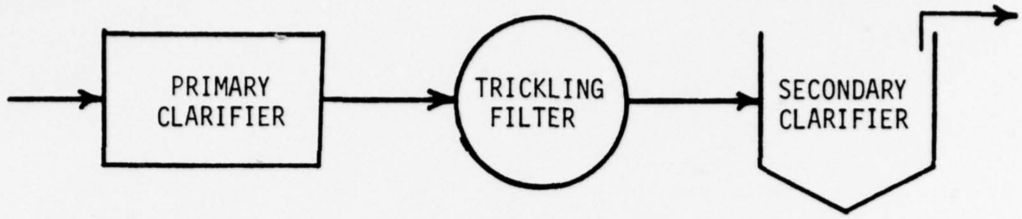
Effects of Process Dynamics

Since the TSM is a steady state model, the influent and predicted effluent concentrations must, of necessity, be averages. If the influent flow rate or concentrations are known to fluctuate drastically, the steady state model predictions are less accurate. The engineer must consider this fact when applying the model and when interpreting the results of the model.

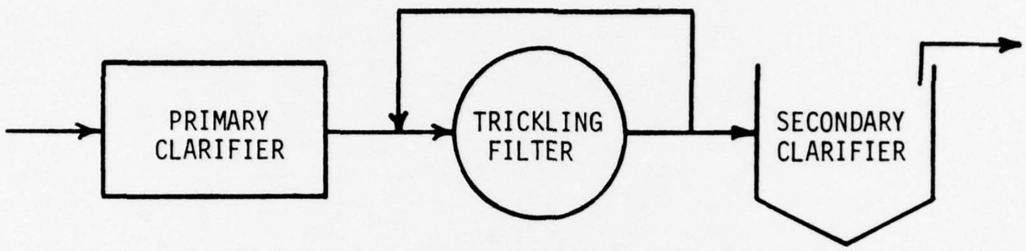
Trickling Filter System

Wastewater treatment systems utilizing the trickling filter can take on many different configurations depending on whether the filters are staged and on the recycle pattern. The model presented here allows for three distinct variations. All three are for single-stage filters, *i.e.*, filters in a parallel but not in series. The first is for no recycle; the second for recycle from the filter effluent; and the third for recycle from the secondary clarifier effluent (see Figures 2 a,b,c).

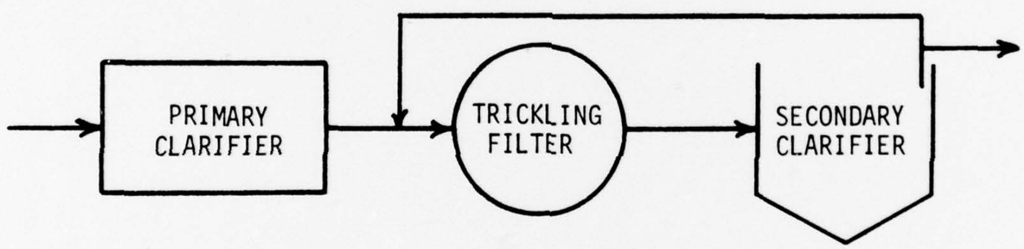
The type of system modeled is controlled by specification of a recirculation data input to the model. If both of the recycle terms are initialized at zero, then a no recycle system is specified. (Figure 2a). If the recycle to the filter is not zero, but recycle from the filter effluent is, then a system with recycle from the secondary clarifier will be modeled (Figure 2c).



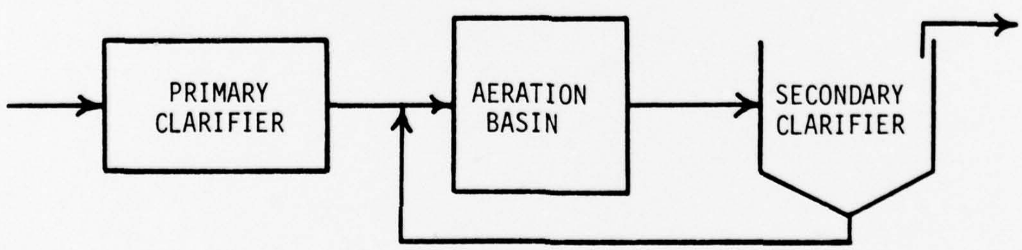
a. Trickling Filter: No Recycle



b. Trickling Filter: Recycle from Trickling Filter Effluent



c. Trickling Filter: Recycle from Secondary Clarifier Effluent



d. Activated Sludge System

Figure 2: Schematic of Treatment Systems

Finally, if the recycle flow rate from the filter is equal to the recycle flow rate to the filter and is not equal to zero, the model simulates a system where recycle is from the filter effluent (Figure 2b).

Other Considerations

Factors which may effect the operation of the system but are not incorporated in the formulation of the model include the effect of the trickling filter media type on the BOD reduction; certain complex interactions between the unit processes; and the additional hydraulic and solids loading imposed on the primary clarifier by wasting secondary sludge to the primary clarifier influent.

One example of complex interactions between unit processes is the effect of the primary clarifier on the performance of the trickling filter. The model predicts the case in which the primary clarifier is overloaded thereby permitting large suspended solids carryover. Conversely, the model does not account for the situation if the high solids concentration in the trickling filter influent were to clog the filter or otherwise degrade its performance. While the exclusion of these and other considerations may result in minor errors, such errors are usually negligible. With an understanding of the structure of the model, as just presented, and a knowledge of the mathematical relationships incorporated in the model, the engineer can utilize the present trickling filter system model to great advantage or modify it to more suitably fit his needs.

Mathematical Relationships

A listing of the expressions that were used in forming the overall model of the trickling filter system follows. These relationships are used to evaluate the operation of the unit processes.

Primary Clarifier[1]

$$RF = \frac{1.0 - 0.82EXP(-Q/2780A)}{1.0 - 0.00205EXP(-Q/2780A)}$$

RF = Removal factor
Q = Plant flow (MGD)
A = Total surface area of clarifier (acres)

$$SS_{out} = SS_{in} * RF$$

$$BOD_{out} = (BOD_{in})(0.3) + (BOD_{in})(RF)(0.7)$$

No effect on ammonia or nitrates

Trickling Filter

BOD reduction [2]

$$E = \frac{1.0}{1.0+0.0085\left(\frac{W}{VF}\right)^{\frac{1}{2}}}$$

E = Decimal BOD removal efficiency
W = BOD loading (lbs/day) to filter (not including recycle)
V = Volume of filter (Acre - Ft)
F = Recirculation factor $\frac{1.0+R}{(1.0+0.1R)^2}$ where $R = \frac{recycle}{influent}$

A temperature correction has also been incorporated [3], [4]

$$E_t = E\,(1.038)^{T-20}$$

E_t = Filter efficiency at temperature, T
E = Filter efficiency as above
T = Temperature of wastewater, deg C

$$BOD_{out} = BOD_{in} * (1.0 - E_t)$$

Suspended Solids [5]

$$\text{Lbs solids produced} = 0.2(\text{lbs } BOD_{in} - \text{lbs } BOD_{out})$$

$$SS_{out} = SS_{in} + \frac{\text{lbs solids produced}}{8.34(\text{flow}+\text{recycle})}$$

Nitrification[6]

$$E = EXP(\,-KD/Q^n)$$

E = Decimal reduction in NH_3-N concentration
K = Reaction constant related to the specific surface of the media
D = Depth of filter (Ft)
Q = Hydraulic loading rate (MGAD)
n = Constant related to the specific surface and configuration of packing

K_{20}=K at 20^{o} C =0.23 1 " rock media
=0.13 2½" rock media

$K=K_{20}(1.07)^{T-20}$ where T is temp. (^{o}C)

n = 2.36 1 " rock media
3.80 2½"rock media

$$[NH_3\text{-}N]_{out} = [NH_3\text{-}N]_{in} * E$$

$$[NO_3\text{-}N]_{out} = [NO_3\text{-}N]_{in} + [NH_3\text{-}N]_{in} - [NH_3\text{-}N]_{out}$$

Secondary Clarifier[1]

The secondary clarifier for the trickling filter

system is assumed to operate similar to the primary and the same equation is utilized. The exception being that only suspended solids removal is considered.

Data Input

Following is a listing of the data input necessary to implement the simulation of a trickling filter plant.

Card 1

Column 1: Type of plant; 1 for trickling filter plant

Columns 2-9: Flow rate to plant (MGD)

Columns 10-17: BOD concentration in wastewater (mg/l)

Columns 18-25: Suspended solids conc. in water (mg/l)

Columns 26-33: Ammonia conc. in water (mg/l NH_3 as N)

Columns 34-41: Nitrate conc. in water (mg/l NO_3 as N)

Columns 42-49: Temperature of water (^{o}C)

Card 2

Columns 1-8: Total surface area of primary clarifier (acres)
(2 clarifiers @ 2 acres ea. = 4 acres)

Card 3

Columns 1-8: Total filter volume (acre-ft)
(2 filters @ 3 acre-ft ea. = 6 acre-ft)

Columns 9-16: Total filter surface area (acres)
(3 filters @ 4 acres ea. = 12 acres)

Columns 17-24: Total recycle to filters (MGD)

Columns 25-32: Total recycle from filter effluent (MGD)

Columns 33-40: Media coefficient (K) 0.23 1" rock media
0.13 2½" rock media

Columns 41-48: Media coefficient (n) 2.36 1" rock media
3.80 2½" rock media

Card 4

Columns 1-8: Total surface area of secondary clarifier (acres)
(2 clarifiers @ 2 acres = 4.0)

Activated Sludge System

As with the trickling filter type of wastewater treatment plant, many different modifications of the activated sludge process exist. The mode of operation of the treatment plant determines which process modification it employs. Of first concern is the fluid regime, *i.e.*, whether the flow is complete-mix or plug-flow. The model presented here is based on complete-mix conditions. It can also be applied to a plug-flow operation though, since the complete-mix formulation generally underestimates the treatment level attainable with a plug-flow system. Because this underestimation is not generally severe, the model can be considered adequate for application to plug-flow systems. The model, therefore, can simulate the complete-mix process including the extended aeration modification of that process, and is acceptable for the plug-flow modification (See Figure 2d).

Specification by the engineer of the type of activated sludge system to be simulated by the model is not necessary. Input of the correct aeration basin operational characteristics will result in a simulation of the appropriate modification.

Aeration Basin Operational Characteristics

Accuracy of the model's predictions is also highly dependent upon the

estimate of the aeration basin's operational characteristics made by the survey engineer. To obtain reliable results, values for the mixed liquor suspended solids, recycle rate, and net yield terms must closely approximate those that exist during actual operation.

While accurate estimates of these characteristics are mandatory, it is often quite difficult to obtain them. The aeration basin's interdependence on the operation of the other unit processes which surround it, especially the secondary clarifier, is the cause of this difficulty. In the situation where the secondary clarifier is underloaded (that is, the sludge blanket is at the bottom), the MLSS is determined solely by the amount of sludge wasted and is easily controlled at the desired level. However, future conditions may result in a critically loaded or overloaded clarifier. This situation is a function of the secondary clarifier solids loading and the settleability of the sludge. Here, the interdependence between aeration basin and secondary clarifier exists and governs what the aeration basin's operational characteristics will be. Should overloading occur, plant failure will result. An overload can not be predicted by the model but must be accounted for by the engineer when he estimates the aeration basin's operational characteristics.

One of the most useful tools for estimating these parameters with accuracy is experience. Comparison of the situation to those currently in existence or in the literature that are similar in nature can also be of considerable aid.

With an understanding of the structure of the activated sludge model as just presented, and a knowledge of the mathematical relationships that describe the operation of the different unit processes in the system, the

engineer should be able to use the model to advantage or modify it to more suitably fit his needs.

Mathematical Relationships

Following is a listing of the expressions that were used in forming the overall model of the activated sludge system.

Primary Clarifier

The relationship is the same as that used for the trickling filter system.

Aeration Basin

BOD reduction[7]

$$BOD_{out} = BOD_{in} - \frac{(MLSS)(Vol)}{(Y_n)(Theta)(FLOWR)}$$

MLSS = Mixed liquor suspended solids (mg/l)
Vol = Aeration basin volume (MG)
Y_n = Net yield (lb SS produced/lb BOD used)
FLOWR = Plant flow + recycle flow (MGD)
Theta = Sludge age or sludge retention time

$$= \frac{1.0}{Y_n(PLI)} \quad \text{where } PLI = \frac{BOD_{in}\,(Flow)}{(MLSS)(Vol)}$$

Nitrification[8]

A double "halving" or Balzano type iteration is performed on the effluent concentrations of ammonia and the nitrifying bacteria, Nitosomonas, until the governing system equations are satisfied:

$$S_i = S_o + \frac{K_r S_o X_o D_t}{Y(K_s + S_o)}$$

$$X_i = X_o - \frac{K_r S_o X_o D_t}{K_s + S_o}$$

where:

S_i = Ammonia in
S_o = Ammonia out
K_r = Synthesis rate constant
Y = Yield coefficient
K_s = Saturation coefficient
X_i = Nitrosomonas in
X_o = Nitrosomonas out
D_t Detention time (Vol/Flow)

A detailed explanation and justification of assumptions may be found in 8.

Secondary Clarifier[9]

$$SS_{out} = 4.5 + 8.6SSF$$

$$SSF = \frac{SS_{in}\ (FR)\ 3.785}{24A} = \text{ Solids surface feed } (kg/m^2 - hr)$$

where: FR = Plant flow + recycle (MGD)
A = Surface area of clarifier (m^2)

Data Input

Following is a listing of the data input necessary to implement the simulation of an activated sludge plant.

Card 1

Column 1: Type of plant: 2 for activated sludge plant

Columns 2-9: Predicted flow to plant (MGD)

Columns 10-17: Predicted BOD of influent (mg/l)

Columns 18-25: Predicted suspended solids of influent (mg/l)

Columns 26-33: Predicted ammonia in influent (mg/l NH_3 as N)

Columns 34-41: Predicted nitrate in influent (mg/l NO_3 as N)

Columns 42-49: Predicted temperature of influent (deg. C)

Card 2

Columns 1-8: Total surface area of primary clarifiers (acres)
(2 clarifiers @ 2 acres ea. = 4 acres)

Card 3

Columns 1-8: Total volume of aeration tanks (MG)
2 tanks @ 3 MG ea. = 6 MG

Columns 9-16: Estimated operating concentration of MLSS (mg/l)

Columns 17-24: Estimated operating recycle rate (MGD)

Columns 25-32: Net yield (lb SS/lb BOD)
If not readily available, calculate:

$$Y_n = \frac{(\text{lb SS wasted/day}) + (\text{effluent SS})(\text{Flow})}{(BOD_{in} - BOD_{out})\text{ Flow}}$$

Card 4

Columns 1-8: Total surface area of secondary clarifiers (acres)
(2 clarifiers @ 2 acres ea. = 4 acres)

III INDICATOR MODEL

Introduction

The indicator model is used to calculate certain parameters, generally termed process variable or operating characteristics, that indicate the operational state of the system. These calculated values can then be compared with the desirable values as cited in design books or manuals [7, 10, 11]. A comparison will give the engineer insight into the operation of the system such that problem areas and possible causes of these problems are more readily apparent. It can also indicate whether inadequate plant performance is due to design deficiencies or poor operational practices.

An example should help to illustrate the use of the indicator model more clearly. If a plant's effluent suspended solids concentration is too high, the engineer might first suspect the secondary clarifier. Solids removal efficiency calculated by the model will indicate whether or not the secondary clarifier is performing poorly. If the secondary clarifier does appear to be performing poorly, operating characteristics such as surface settling rate and solids loading rate, calculated by the model, can be compared to those suggested in the literature. If the clarifier is failing due to a hydraulic overload, comparison of the surface settling rate to common values should indicate this. If the operational characteristics of the secondary clarifier compare favorably with those in the literature, but it still appears to be failing, an investigation of the

operational characteristics of the other unit processes might be helpful. Should the process loading intensity of the aeration basin not compare favorably with cited values, a poorly settling sludge might well be the cause of the secondary clarifier's failure.

Operational Characteristics

Like the treatment system model, the indicator model is applicable to trickling filter and activated sludge type treatment plants. Operational characteristics calculated by the model are as follows:

<u>Primary Clarifier</u>

Detention time (hrs)

Surface settling rate (GPD/ft^2)

Weir overflow rate (GPD/ft)

Solids loading rate (lb SS/ft^2-day)

Solids removal efficiency (%)

<u>Trickling Filter</u>

Hydraulic loading (MGAD)

Organic loading (lb BOD/day/acre-ft)

Recirculation ratio

BOD removal efficiency (%)

<u>Aeration Basin</u>

Detention time (hrs)

Volumetric loading (lb BOD/day/1000 ft^3)

Process loading intensity (lb BOD/day/lb MLSS)

Sludge age or retention time (days)

Diffused aeration

Volumetric air supply (CFM/1000 ft^3)

Organic air supply (ft^3/lb BOD)

Mechanical aeration

Volumetric power supply (HP/1000 ft^3)

Organic oxygen supply (lb oxygen/lb BOD)

BOD removal efficiency (%)

Secondary Clarifier

Detention time (hrs)

Surface settling rate (GPD/ft^2)

Weir overflow rate (GPD/ft)

Solids loading rate (lb SS/day/ft^2)

Solids removal efficiency (%)

Overall Plant

BOD removal efficiency (%)

Solids removal efficiency (%)

Mathematical Relationships

Each of the operational characteristics calculated by the model is represented by a mathematical expression. Many of these expressions are evaluated at both average and peak flow conditions. This is done by using either the average or peak flow term in the expression. However,

this may not always be completely accurate, as the BOD suspended solids concentrations also vary diurnally. Peak values for the operational characteristics, therefore, may be in error because only the peak flows and not the peak concentrations were used in the calculations. Such error may be overcome, if desired, by substituting the peak values of these parameters (BOD, flow, etc.) for the average values as input data and running the model another time. Values of the operational characteristics calculated on this second run, which are printed out as average, will then represent the peak values. Following is a listing of the relationships:

Primary Clarifier

Detention time: $$DT = \frac{V}{1000\ F/24}$$

V = clarifier volume (1000 gal)
F = plant flow (MGD)

Surface settling rate:

$$SSR = \frac{F * 10^6}{A}$$

F = plant flow (MGD)
A = clarifier surface area (ft^2)

Weir overflow rate:

$$WOR = \frac{F * 10^6}{L}$$

F = plant flow (MGD)
L = weir length (ft)

Solids loading:

$$SL = \frac{(SS)\ (F)\ (8.34)}{A}$$

SS = influent suspended solids (mg/l)
F = plant flow (MGD)
A = clarifier surface area (ft^2)

Solids removal efficiency:

$$SRE = \frac{SSI - SSO}{SSI} * 100.$$

SSI = plant influent suspended solids (mg/l)
SSO = primary effluent suspended solids (mg/l)

<u>Trickling Filter</u>

Hydraulic loading:

$$HL = \frac{F + R}{A}$$

F = plant flow (MGD)
R = recycle flow to filter (MGD)
A = filter surface area (acres)

Organic loading:

$$OL = \frac{(F)\ (BOD)\ (8.34)}{V}$$

F = plant flow (MGD)
BOD = primary effluent BOD (mg/l)
V = filter volume (acre-ft)

Recirculation ratio:

$$RR = \frac{R}{F}$$

F = plant flow (MGD)
R = recycle flow to filter (MGD)

BOD removal efficiency:

$$E = \frac{BOD_1 - BOD_0}{BOD_1} * 100.$$

BOD_1 = primary effluent BOD (mg/l)
BOD_0 = plant effluent BOD (mg/l)

<u>Aeration Basin</u>

Detention time:

$$DT = \frac{24V}{(F+R)1000}$$

Aeration Basin (Continued)

V = aeration basin volume (1000)
F = plant flow (MGD)
R = recycle flow (MGD)

Volumetric loading:

$$VL = \frac{(BOD)\ (F)\ (8.34)\ (7.481)}{V}$$

BOD = primary effluent BOD (mg/l)

Process loading intensity:

$$PLI = \frac{(BOD)\ (F)\ (8.34)\ (1000)}{(MLSS)\ (V)\ (8.34)}$$

BOD = primary effluent BOD (mg/l)
F = plant flow (MGD)
MLSS= mixed liquor suspended solids (mg/l)
V = aeration basin volume (1000 gal)

Sludge age:

$$SA = \frac{(MLSS)(0.001V)(8.34)}{(F_w)(RSS)(8.34) + (F-F_w)(SS)(8.34)}$$

MLSS= mixed liquor suspended solids (mg/l)
V = aeration basin volume (1000 gal)
F_w = waste sludge flow rate (MGD)
RSS = return sludge suspended solids (mg/l)
F = plant flow (MGD)
SS = plant effluent suspended solids (mg/l)

A basic assumption made in the sludge age formulation is that sludge wasting is from the sludge recycle line. If the wasting is from the aeration basin, the actual waste sludge flow rate must be adjusted before input to the model.

$$F_i = \frac{(Fa)\ (MLSS)}{RSS}$$

F_i = input waste sludge flow (GPD)
F_a = actual waste sludge flow (GPD)
MLSS= mixed liquor suspended solids (mg/l)
RSS = return sludge suspended solids (mg/l)

Volumetric air supply:

$$VAS = \frac{(AV)(1000)(7.481)}{(24)(60)(V)}$$

AV = volume of air delivered (1000 ft^3/day)
V = aeration basin volume (1000 gal)

Organic air supply:

$$OAS = \frac{(AV)(1000)}{(BOD)(F)\ (8.34)}$$

AV = volume of air delivered (1000 ft^3/day)
BOD = primary effluent BOD (mg/l)
F = plant flow (MGD)

Volumetric power supply:

$$VPS = \frac{7.481\ HP}{V}$$

HP = total aerator horsepower (HP)
V = aeration basin volume (1000 gal)

Organic oxygen supply:

$$OAS = \frac{(N)(HP)(HR)}{(BOD)(F)(8.34)}$$

N = oxygen transfer rate (lb O_2/HP-hr)
HP = total aerator horsepower (HP)
HR = hours of aerator operation (hr/day)
BOD = primary effluent BOD (mg/l)
F = plant flow (MGD)

$$N = (2.5)\ \frac{CS-C}{9.17}\ (1.024)\ T\text{-}20\ (0.8)$$

CS = D.O. saturation in aeration basin (mg/l)
C = D.O. conc. in aeration basin (mg/l)
T = plant effluent temperature (°C)

A basic assumption made in the organic oxygen supply formulation is that the mechanical aerators employed are rated at 2.5 lb O_2/HP-hr under standard conditions as defined in [7]. Also assumed is an alpha

value for the wastewater of 0.8. If the engineer has the actual values of these parameters for the system being investigated, the model should be changed accordingly.

BOD removal efficiency:

$$E = \frac{BOD_i - BOD_o}{BOD_o} * 100.$$

BOD_i = primary effluent BOD (mg/l)
BOD_o = plant effluent BOD (mg/l)

Secondary Clarifier

For the secondary clarifier, the flow to the clarifier depends on whether it is part of a trickling filter or activated sludge type system. For the trickling filter system, the flow to the clarifier is equal to the plant flow plus the recycle to the filter minus the recycle from the filter effluent. For the activated sludge system, the flow to the clarifier is equal to the plant flow plus the recycle sludge flow.

Detention time:

$$DT = \frac{V}{1000\ F/24}$$

V = clarifier volume (1000 gal)
F = flow to clarifier (MGD)

Surface settling rate:

$$SSR = \frac{F * 10^6}{A}$$

F = flow to clarifier (MGD)
A = clarifier surface area (ft^2)

Weir overflow rate:

$$WOR = \frac{F * 10^6}{L}$$

F = flow to clarifier (MGD)
L = weir length (ft)

Solids loading rate:

$$SL = \frac{(SS)(F)(8.34)}{A}$$

SS = aeration basin or trickling filter effluent suspended solids (mg/l)
F = flow to clarifier (MGD)

Solids removal efficiency:

$$E = \frac{SSI - SSO}{SSO} * 100$$

SSI = aeration basin or trickling filter effluent suspended solids (mg/l)
SSO = plant effluent suspended solids (mg/l)

Data Input

The indicator model is designed to use data that is available prior to a survey's implementation and also the data generated by the survey. Design data needed should, of course, always be available. Operational data required will be available from the daily and monthly operation logs as required by Technical Manual 5-665, and then from the data generated by the survey. (If the value of any parameter is not available, it should be replaced by - 1.0 in the appropriate columns for the data input.) A listing of the data input necessary to implement the indicator model

follows:

Trickling Filter Type Plant

Card 1

Column 1: Plant type; 1 for trickling filter type plant.

Columns 2-41: Name of installation e.g. Fort Ord, CA (Should be centered)

Card 2 - Primary Clarifier

Columns 1-8: Total volume (1000 gal) (2 clarifiers @ 4000 gal ea. = 8.0)

Columns 9-16: Total surface area (Ft^2) (2 clarifiers @ 200 Ft^2 ea. = 400.)

Columns 17-24: Total weir length (Ft) (2 clarifiers @ 500 Ft ea. = 1000.)

Columns 25-32: Design flow rate (MGD)

Columns 33-40: Design detention time (Hrs) If not readily available, calculate

$$DT = \frac{\text{Total Vol (1000 gal)} \times 0.024}{\text{Design flow (MGD)}}$$

Columns 41-48: Design surface settling rate (GPD/Ft^2) If not readily available, calculate

$$SSR = \frac{\text{Design flow (MGD)} \times 10^6}{\text{Total surface area } (Ft^2)}$$

Columns 49-56: Design weir overflow rate (GPD/Ft) If not readily available, calculate

$$WOR = \frac{\text{Design flow (MGD)} \times 10^6}{\text{Total weir length (Ft)}}$$

Card 3 - Trickling Filter

Columns 1-8: Design flow rate (MGD)

Columns 9-16: Design organic loading (Lb BOD/Acre-Ft/Day)

Columns 17-24: Total volume (Acre-Ft)
(2 filters @ 3 acre-ft ea. = 6.)

Columns 25-32: Total area (Acres)
(2 filters @ .75 acres ea. = 1.5)

Columns 33-40: Total design recycle per day (MG)
If not readily available, calculate

R = Design percent recycle X 100. X Design flow (MGD)

Card 4 - Secondary Clarifier

Columns 1-8: Total volume (1000 Gal)
(2 clarifiers @ 4000 gal ea. = 8.0)

Columns 9-16: Total surface area (Ft^2)
(2 clarifiers @ 200 Ft^2 ea. = 400.)

Columns 17-24: Total weir length (Ft)
(2 clarifiers @ 500 Ft ea. = 1000.)

Columns 25-32: Design flow rate (MGD)

Columns 33-40: Design detention time (Hrs)
If not readily available, calculate

$$DT = \frac{\text{Total Vol (1000 gal) X 0.024}}{\text{Design flow (MGD)}}$$

Columns 41-48: Design surface settling rate (GPD/Ft^2)
If not readily available, calculate

$$SSR = \frac{\text{Design flow (MGD) X } 10^6}{\text{Total surface area } (Ft^2)}$$

Columns 49-56: Design weir overflow rate (GPD/Ft)
If not readily available, calculate

$$WOR = \frac{\text{Design flow (MGD) X } 10^6}{\text{Total weir length (Ft)}}$$

Columns 57-64: Design solids loading (Lb SS/Ft^2-Day)

Card 5 - General Operations

Columns 1-8: Peak flow (influent) (MGD)

Columns 9-16: Total daily flow (influent) (MG)

Columns 17-24: BOD (influent) (mg/l)

Columns 25-32: Suspended solids (influent) (mg/l)

Columns 33-40: BOD (effluent) (mg/l)

Columns 41-48: Suspended solids (effluent) (mg/l)

Card 6 - Process Operations

Columns 1-8: Primary clarifier effluent BOD (mg/l)

Columns 9-16: Primary effluent suspended solids (mg/l)

Columns 17-24: Trickling filter effluent BOD (mg/l)

Columns 25-32: Filter effluent suspended solids (mg/l)

Columns 33-40: Total recycle to filter (MGD)

Columns 41-48: Total recycle from filter effluent (MGD)

Columns 49-56: Recycle from secondary clarifier (MGD)

Activated Sludge Type Plant

Card 1

Column 1: Plant type; 2 for activated sludge type plant.

Columns 2-41: Same as for trickling filter type plant.

Card 2 - Primary Clarifier

Same as for trickling filter type plant.

Card 3 - Aeration Tanks

Columns 1-8: Total tank volume (1000 Gal)
(2 tanks @ 50,000 gal ea. = 100.)

Columns 9-16: Design flow rate (MGD)

Columns 17-24: Design detention time (Hrs)
If not readily available, calculate

$$DT = \frac{\text{Total Vol (1000 Gal)} \times 0.024}{\text{Design flow (MGD)}}$$

Columns 25-32: Design organic loading (Lb BOD/day/1000 Ft^3)

Columns 33-40: Design mixed liquor suspended solids (mg/l)

Columns 41-48: Number of aerators or compressors

Columns 49-56: Total aerator or compressor horsepower (2 aerators @ 50 HP ea. = 100.)

Card 4 - Secondary Clarifier

Same as for trickling filter type plant.

Card 5 - General Operations

Same as for trickling filter type plant with the exception of:

Columns 49-56: Average temperature of plant effluent (C)

Columns 57-64: D.O. saturation in aeration basin (mg/l)

Card 6 - Process Operations

Columns 1-8: Primary clarifier effluent BOD (mg/l)

Columns 9-16: Primary effluent suspended solids (mg/l)

Columns 17-24: Mixed liquor suspended solids (mg/l)

Columns 25-32: Volume of air delivered (1000 ft^3/day)

Columns 33-40: Average mech. aerator operating time (hrs/day) This should be computed by multiplying the time of operation of each aerator by its horsepower and summing to get the total. This horsepower-hour total should then be divided by the total aerator horsepower.

Columns 41-48: Recycle sludge volume (MGD)

Columns 49-56: Recycle sludge suspended solids (mg/l)

Columns 57-64: Wasted sludge volume (GPD)

Columns 65-72: Average aeration basin dissolved oxygen (mg/l)

BIBLIOGRAPHY

1. Smith, R., Publication WP-20-9 Water Pollution Control Research Series, F.W.P.C.A., (Washington, 1968).

2. "Sewage Treatment at Military Installations.", National Research Council, Sewage Works Journal, 18, No. 5, pp. 787-1,028 (1946).

3. Howard, W.E., "Flow Over Porous Media as in a Trickling Filter." Proceedings - 12th Purdue Industrial Waste Conference, Lafayette, Indiana, pp. 435-465 (1957).

4. Eckenfelder, W.W., Industrial Water Pollution Control, New York: McGraw-Hill Book Company (1966).

5. Vesilind, P. Aarne, Treatment and Disposal of Waste Water Sludges, Ann Arbor Science, Ann Arbor, Mi. (1974).

6. Balakrishnan, S. and W.W. Eckenfelder. "Nitrogen Relationships in Biological Treatment Processes. II. Nitrification in Trickling Filters.", Water Research, 3:167, 1969.

7. Wastewater Engineering, Metcalf and Eddy, Inc., McGraw-Hill Book Company, N.Y., N.Y., (1972).

8. Smith, R. and Richard G. Eilers, "A Generalized Computer Model for Steady-State Performance of the Activated Sludge Process", Water Pollution Control Research Report, F.W.P.C.A. (Washington, 1969).

9. Pflanz, P., "The Sedimentation of Activated Sludge in Final Settling Tanks". Journal International Association of Water Pollution Research, Vol. 2, No. 1, Jan. 1968, pp. 80-86.

10. Process Design Manual for Upgrading Existing Wastewater Treatment Plants, U.S. EPA, Office of Technology Transfer, (Washington, 1974).

11. Rich, L.G., Environmental Systems Engineering, McGraw-Hill Book Company, N.Y., N.Y., (1973).

12. Andrews, J.F., "Application of Some Systems Engineering Concepts and Tools to Water Pollution Control Systems." In Symposium on the use of Mathematical Models for Water Pollution Control. University of Newcastle Upor Tyne, London. 1973. p.30.

APPENDIX A

Listing of Treatment System Model

<u>MAIN</u> - MAIN reads in the predicted future influent data. Then, it routes the logic to either TFILT or ACTS depending on whether the simulation is for a trickling filter or activated sludge type system. Finally, MAIN prints out the estimated future effluent conditions returned to it by the subprograms.

<u>TFILT</u> - Subroutine TFILT first calls PCLAR which is the primary clarifier subroutine. Then, TFILT reads in the trickling filter data and, using the output from PCLAR as input to the filter, claculates the filter output. If required, subroutine TFNIT is called to calculate the filter nitrification. The output from the filter is then passed to subroutine TFSEC (the secondary clarifier subroutine) and the systems final effluent is determined and returned to MAIN.

<u>TFNIT</u> - Subroutine TFNIT takes the data passed from TFILT, determines the filter nitrification and returns this to TFILT.

<u>TFSEC</u> - Subroutine TFSEC takes the data passed to it from TFILT. Then, it reads in the secondary clarifier data, calculates the plant's final effluent and returns this to TFILT.

<u>ACTS</u> - Subroutine ACTS first calls PCLAR which is the primary clarifier subroutine. Then, ACTS reads in the aeration basin data and, using the output from PCLAR as input to the basin, calculates the basin output. If required, subroutine ACTNIT is called to calculate the basin nitrification. The output from the basin is then passed to subroutine ACTSEC (the secondary clarifier subroutine) and the systems final effluent is determined and returned to MAIN.

ACTNIT - Subroutine ACTNIT takes the data passed from ACTS, determines the aeration basin nitrification and returns it to ACTS.

ACTSEC - Subroutine ACTSEC takes the data passed from ACTS. Then, it reads in the secondary clarifier data, calculates the plant's final effluent and returns it to ACTS.

PCLAR - Subroutine PCLAR may be called by either TFILT or ACTS. PCLAR takes the plants influent data passed to it by one of these subroutines. It then reads in the primary clarifier data, calculates the clarifier output and returns it to the subroutine that called it.

```
C
C
C
C   STEADY STATE TREATMENT PLANT MODEL
C   MODEL TO SIMULATE TRICKLING FILTER
C   OR ACTIVATED SLUDGE TYPE PLANT
C
      DIMENSION TYP(4,2)
      REAL NH3,NO3
      COMMON FLOW
      DATA TYP(1,1),TYP(2,1),TYP(3,1),TYP(4,1)
     1  /'TRIC','KLIN','G FI','LTER'/,
     2  TYP(1,2),TYP(2,2),TYP(3,2),TYP(4,2)
     3  /'ACTI','VATE','D SL','UDGE'/
      READ(1,100)ITYP,FLOW,BOD,SS,NH3,NO3,TEMP
      WRITE(3,110)(TYP(I,ITYP),I=1,4)
      WRITE(3,115)FLOW,BOD,SS,NH3,NO3,TEMP
      GO TO (10,20),ITYP
   10 CALL TFILT(BOD,SS,NH3,NO3,TEMP,&30)
   20 CALL ACTS(BOD,SS,NH3,NO3,TEMP,&30)
   30 WRITE(3,12C)BOD,SS,NH3,NO3
      STCP
  1CO FORMAT(I1,6F8.0)
  110 FORMAT(1H1,//'  ESTIMATE OF PLANT PERFCRMANCE AFTER ',
     1  'INSTALLATION EXPANSION'/16X,4A4,' TYPE PLANT'//
     2  5X,'PREDICTED FUTURE INFLUENT CONDITICNS'/)
  115 FORMAT(10X,'FLOW RATE=',T30,F8.2,2X,'(MGD)'/
     1  10X,'BOD=',T30,F8.2,2X,'(MG/L)'/
     2  10X,'SUSPENDED SOLIDS=',T30,F8.2,2X,'(MG/L)'/
     3  10X,'AMMONIA=',T30,F8.2,2X,'(MG/L)'/
     4  10X,'NITRATE=',T30,F8.2,2X,'(MG/L)'/
     5  10X,'TEMPERATURE=',T30,F8.2,2X,'(DEGREES C)')
  120 FORMAT(///5X,'ESTIMATED FUTURE EFFLUENT CONDITIONS'/
     2  10X,'BOD=',T30,F8.2,2X,'(MG/L)'/
     3  10X,'SUSPENDED SOLIDS=',T30,F8.2,2X,'(MG/L)'/
     4  10X,'AMMONIA=',T30,F8.2,2X,'(MG/L)'/
     5  10X,'NITRATE=',T30,F8.2,2X,'(MG/L)')
      END
```

```
C
C
C
      SUBROUTINE TFILT(BOD,SS,NH3,NO3,TEMP,*)
      COMMON FLOW
      REAL NH3,NO3,K20,NN
      DATA YTFSS /0.2/
      CALL PCLAR(BOD,SS)
      READ(1,110)V,A,R1,R2,K20,NN
      WRITE(3,120)V,A,R1,R2,K20,NN
      W=BOD*FLOW*8.34
      R=R1/FLOW
      F=(1.0+R)/(1.0+.1*R)**2
      E=1.0/(1.0+0.0085*(W/(V*F))**.5)
      E=E*1.038**(TEMP-20.)
      IF(E .GT. .95)E=.95
      E=1.-E
      SS=SS+YTFSS*(BOD*8.34*FLOW-E*BOD*8.34*(FLOW+R1))/(8.34*(FLOW+R1))
      BOD=BOD*E
      Q=(FLOW+R1)/A
      D=V/A
      IF(NH3 .GT. 0.)CALL TFNIT(NH3,NO3,TEMP,K20,NN,D,Q)
      CALL FTSEC(SS,R1,R2)
      RETURN1
  110 FORMAT(6F8.0)
  120 FORMAT(//10X,'TRICKLING FILTER CHARACTERISTICS'/
     1  15X,'TOTAL FILTER VOLUME=',T40,F8.2,2X,'(ACRE-FT)',/
     2  15X,'TOTAL FILTER AREA=',T40,F8.2,2X,'(ACRES)',/
     3  15X,'RECYCLE TO FILTER=',T40,F8.2,2X,'(MGD)',/
     4  15X,'RECYCLE FROM FILTER=',T40,F8.2,2X,'(MGD)'/
     5  15X,'MEDIA COEFFICIENT (K)=',T40,F8.2/
     6  15X,'MEDIA COEFFICIENT (N)=',T40,F8.2)
      END
```

```
C
C
C
      SUBROUTINE TFNIT(NH3,NO3,TEMP,K2C,NN,D,Q)
      COMMON FLOW
      REAL NH3,NC3,K20,K20,NN
      K20=K20*1.07**(TEMP-20.)
      E=EXP(-K20*D/Q**NN)
      NO3=NO3+NH3-NH3*E
      NH3=NH3*E
      RETURN
      END
```

```
C
C
C
      SUBROUTINE TFSEC(SS,R1,R2)
      COMMON FLOW
      READ(1,10)A
      WRITE(3,100)A
      FLO=FLOW+R1-R2
      RF=(1.0-0.82*EXP(-FLO /(2780.0*A)))/(1.0-0.00205*EXP(-FLO /
     1  (2780.0*A)))
      SS=SS*RF
      RETURN
   10 FORMAT(F8.0)
  100 FORMAT(//10X,'SECONDARY CLARIFIER CHARACTERISTICS'/
     1  15X,'AREA=',T40,F8.2,2X,'(ACRES)')
      END
```

```
C
C
C
      SUBROUTINE ACTS(BOD,SS,NH3,NO3,TEMP,*)
      COMMON FLOW
      REAL MLSS,NH3,NO3
      CALL PCLAR(BOD,SS)
      READ(1,100)VOL,MLSS,R,YN
      WRITE(3,120)VOL,MLSS,R,YN
      PLI=BOD*FLOW/(MLSS*VOL)
      IF(PLI .GT. 0.4)WRITE(3,130)PLI
      THETA=1.0/(YN*PLI)
      FLOWR=FLOW+R
      BOD=BOD-MLSS*VOL/(YN*THETA*FLOWR)
      SS=MLSS
      IF(NH3 .GT. 0.)CALL ACTNIT(NH3,NO3,FLOWR,VOL,THETA,TEMP)
      CALL ACTSEC(SS,FLOWR)
      RETURN1
  100 FORMAT(4F8.0)
  120 FORMAT(//10X,'ACTIVATED SLUDGE CHARACTERISTICS'/
     1  15X,'TOTAL AERATION BASIN VOLUME=',T50,F8.2,2X,'(MG)'/
     2  15X,'MIXED LIQUOR SUSPENDED SOLIDS=',T50,F8.2,2X,'(MG/L)'/
     3  15X,'TOTAL SLUDGE RECYCLE=',T50,F8.2,2X,'(MGD)'/
     4  15X,'NET YIELD=',T50,F8.2,2X,'(LBS SOLIDS PRODUCED/'/
     5  T62,'LB BOD UTILIZED)')
  130 FORMAT(/5X,10('*'),'PLI=',F5.2/
     1  15X,'THIS PLI MAY CAUSE POORLY SETTLING SLUDGE'/
     2  15X,'AND INABILITY TO MAINTAIN ESTIMATED MLSS')
      END
```

```
C
C
C
      SUBROUTINE ACTNIT(NH3,NO3,FLOWR,VOL,THETA,TEMP)
      COMMON FLOW
      REAL NH3,NO3,NKS,NKR
      DATA Y,NKS/0.05,1.0/
      R1=FLOWR-FLOW
      TEMP1=VOL/THETA
      NKR=0.33*1.123**(TEMP-20.)
      DT=VOL/FLOWR
      X21=Y*FLOW*NH3*THETA/VOL
      XLOW=0.
      XUP=2.*X21
      IX=0
   10 S21=.5*NH3
      SLOW=0.
      SUP=NH3
      IS=0
   15 S22=S21+(NKR*S21*X21*DT)/(Y*(NKS+S21))
      X22=X21-(NKR*S21*X21*DT)/(NKS+S21)
      S17=(S22*FLOWR-NH3*FLOW)/R1
      X17=X22*FLOWR/R1
      DS2=S21-S17
      IF(ABS(DS2)-0.01)29,29,22
   22 IF(IS-20)24,29,29
   24 IF(DS2)27,27,25
   25 SLOW=S21
      S21=S21+0.5*(SUP-SLOW)
      IS=IS+1
      GO TO 15
   27 SUP=S21
      S21=S21-0.5*(SUP-SLOW)
      IS=IS+1
      GO TO 15
   29 X1=FLOWR*X21
      X2=FLOWR*X22
      X2=(X1-X2)/X21
      DX2=TEMP1-X2
      IF(ABS(DX2)-0.1)50,50,30
   30 IF(X21-0.001)40,40,32
   32 IF(IX-20)31,40,40
   31 IF(DX2)37,37,35
   35 XUP=X21
      X21=X21-0.5*(XUP-XLOW)
      IX=IX+1
      GO TO 10
   37 XLOW=X21
      X21=X21+0.5*(XUP-XLOW)
      IX=IX+1
      GO TO 10
   50 NO3=NO3+NH3-S21
      NH3=S21
   40 CONTINUE
      RETURN
      END
```

```
C
C
C
      SUBROUTINE ACTSEC(SS,FLOWR)
      COMMON FLOW
      READ(1,100)A
      WRITE(3,110)A
      A=A*4047.
      SSF=SS*FLOWR*3.785/24./A
      SS=4.5+8.6*SSF
      RETURN
  100 FORMAT(F8.0)
  110 FORMAT(//10X,'SECONDARY CLARIFIER CHARACTERISTICS'/
     1  15X,'AREA=',T40,F8.2,2X,'(ACRES)')
      END
```

```
C
C
C
      SUBROUTINE PCLAR(BOD,SS)
      COMMON FLOW
      READ(1,10)A
      WRITE(3,100)A
      RF=(1.0-0.82*EXP(-FLOW/(2780.0*A)))/(1.0-0.00205*EXP(-FLOW/
     1  (2780.0*A)))
      SS=SS*RF
      BOD=0.3*BOD+0.7*BOD*RF
      RETURN
   10 FORMAT(F8.0)
  100 FORMAT(//10X,'PRIMARY CLARIFIER CHARACTERISTICS'/
     1  15X,'AREA=',T40,F8.2,2X,'(ACRES)')
      END
```

APPENDIX B

Output From Treatment System Model Program

ESTIMATE OF PLANT PERFORMANCE AFTER INSTALLATION EXPANSION
TRICKLING FILTER TYPE PLANT

PREDICTED FUTURE INFLUENT CONDITIONS

FLOW RATE=	14.60	(MGD)
BOD=	148.00	(MG/L)
SUSPENDED SOLIDS=	163.00	(MG/L)
AMMONIA=	0.0	(MG/L)
NITRATE=	0.0	(MG/L)
TEMPERATURE=	15.00	(DEGREES C)

PRIMARY CLARIFIER CHARACTERISTICS

AREA=	0.84	(ACRES)

TRICKLING FILTER CHARACTERISTICS

TOTAL FILTER VOLUME=	4.56	(ACRE-FT)
TOTAL FILTER AREA=	1.52	(ACRES)
RECYCLE TO FILTER=	0.0	(MGD)
RECYCLE FROM FILTER=	0.0	(MGD)
MEDIA COEFFICIENT (K)=	0.23	
MEDIA COEFFICIENT (N)=	2.36	

SECONDARY CLARIFIER CHARACTERISTICS

AREA=	0.43	(ACRES)

ESTIMATED FUTURE EFFLUENT CONDITIONS

BOD=	39.10	(MG/L)
SUSPENDED SOLIDS=	6.69	(MG/L)
AMMONIA=	0.0	(MG/L)
NITRATE=	0.0	(MG/L)

ESTIMATE OF PLANT PERFORMANCE AFTER INSTALLATION EXPANSION
TRICKLING FILTER TYPE PLANT

PREDICTED FUTURE INFLUENT CONDITIONS

FLOW RATE=	2.00	(MGD)
BOD=	250.00	(MG/L)
SUSPENDED SOLIDS=	500.00	(MG/L)
AMMONIA=	20.00	(MG/L)
NITRATE=	0.0	(MG/L)
TEMPERATURE=	15.00	(DEGREES C)

PRIMARY CLARIFIER CHARACTERISTICS

AREA=	0.50	(ACRES)

TRICKLING FILTER CHARACTERISTICS

TOTAL FILTER VOLUME=	5.00	(ACRE-FT)
TOTAL FILTER AREA=	0.75	(ACRES)
RECYCLE TO FILTER=	2.00	(MGD)
TOTAL RECYCLE FROM FILTE	2.00	(MGD)
MEDIA COEFFICIENT (K)=	0.23	
MEDIA COEFFICIENT (N)=	2.36	

SECONDARY CLARIFIER CHARACTERISTICS

AREA=	0.50	(ACRES)

ESTIMATED FUTURE EFFLUENT CONDITIONS

BOD=	78.78	(MG/L)
SUSPENDED SOLIDS=	15.56	(MG/L)
AMMONIA=	19.58	(MG/L)
NITRATE=	0.42	(MG/L)

APPENDIX C

Listing of Indicator Model Program

```
C  BOX 5718
C  ROGER B. SMITH
C
C
C
      DIMENSION PLDES(4,2),UNIT(4,4)
      COMMON A(9,6),PLANT(10)
      DATA PLDES(1,2),PLDES(2,2),PLDES(3,2),PLDES(4,2)
     1  /'ACTI','VATE','D SL','UDGE'/,
     2      PLDES(1,1),PLDES(2,1),PLDES(3,1),PLDES(4,1)
     3  /'TRIC','KLIN','G FI','LTER'/
      DATA UNIT(1,1),UNIT(2,1),UNIT(3,1),UNIT(4,1)
     1  /'PRIM','ARY ','SETT','LING'/,
     2      UNIT(1,2),UNIT(2,2),UNIT(3,2),UNIT(4,2)
     3  /' AER','ATIO','N TA','NKS '/,
     4      UNIT(1,3),UNIT(2,3),UNIT(3,3),UNIT(4,3)
     5  /'FINA','L CL','ARIF','IER '/
      DATA UNIT(1,4),UNIT(2,4),UNIT(3,4),UNIT(4,4)
     1  /'TRIC','KLIN','G FI','LTER'/
C
C
C
      READ(1,901) NPTYP,PLANT
      WRITE(3,902)
      WRITE(3,908)PLANT
      WRITE(3,905)(PLDES(I,NPTYP),I=1,4)
      WRITE(3,903)
C          DETERMINE PROCESS TYPE
      GO TO (90,80),NPTYP
C
C  ACTIVATED SLUDGE TYPE PLANT
C
   80 READ(1,906)(A(I,1),I=1,7)
C
C          PRIMARY CLARIFIER
C     A(1,1)=TOTAL TANK VOLUME (1000 GAL)
C     A(2,1)=TOTAL SURFACE AREA (FT2)
C     A(3,1)=TOTAL WEIR LENGTH (FT)
C     A(4,1)=DESIGN FLOW RATE (MGD)
C     A(5,1)=DESIGN DETENTION PERIOD (HRS)
C     A(6,1)=DESIGN SURFACE SETTLING RATE (GPD/FT2)
C     A(7,1)=DESIGN WEIR OVERFLOW RATE (GPD/FT)
C
      WRITE(3,904)(UNIT(I,1),I=1,4)
      IF(A(1,1) .LT. 0.0)WRITE(3,910)
      IF(A(2,1) .LT. 0.0)WRITE(3,911)
      IF(A(3,1) .LT. 0.0)WRITE(3,912)
      IF(A(4,1) .LT. 0.0)WRITE(3,913)
      IF(A(5,1) .LT. 0.0)WRITE(3,914)
      IF(A(6,1) .LT. 0.0)WRITE(3,915)
      IF(A(7,1) .LT. 0.0)WRITE(3,916)
C
      READ(1,906)(A(I,2),I=1,7)
C
C          AERATION BASIN
C     A(1,2)=TOTAL TANK VOLUME (1000 GAL)
C     A(2,2)=DESIGN FLOW RATE (MGD)
C     A(3,2)=DESIGN DETENTION PERIOD (HRS)
```

```
C      A(4,2)=DESIGN ORGANIC LOADING (LB BOD/DAY/1000 FT3)
C      A(5,2)=DESIGN MLSS (MG/L)
C      A(6,2)=NUMBER OF AERATORS OR COMPRESSORS
C      A(7,2)=TOTAL AERATOR OR COMPRESSOR HORSEPOWER
C
       WRITE(3,904)(UNIT(I,2),I=1,4)
       IF(A(1,2) .LT. 0.0)WRITE(3,920)
       IF(A(2,2) .LT. 0.0)WRITE(3,921)
       IF(A(3,2) .LT. 0.0)WRITE(3,922)
       IF(A(4,2) .LT. 0.0)WRITE(3,923)
       IF(A(5,2) .LT. 0.0)WRITE(3,924)
       IF(A(6,2) .LT. 0.0)WRITE(3,925)
       IF(A(7,2) .LT. 0.0)WRITE(3,926)
C
       READ(1,906)(A(I,3),I=1,8)
C
C           FINAL CLARIFIER
C      A(1,3)=TOTAL TANK VOLUME (1000 GAL)
C      A(2,3)=TOTAL SURFACE AREA (FT2)
C      A(3,3)=TOTAL WEIR LENGTH (FT)
C      A(4,3)=DESIGN FLOW RATE (MGD)
C      A(5,3)=DESIGN DETENTION PERIOD (HRS)
C      A(6,3)=DESIGN SURFACE SETTLING RATE (GPD/FT2)
C      A(7,3)=DESIGN WEIR OVERFLOW RATE (GPD/FT)
C      A(8,3)=DESIGN SOLIDS LOADING (LB SS/DAY/FT2)
C
       WRITE(3,904)(UNIT(I,3),I=1,4)
       IF(A(1,3) .LT. 0.0)WRITE(3,910)
       IF(A(2,3) .LT. 0.0)WRITE(3,911)
       IF(A(3,3) .LT. 0.0)WRITE(3,912)
       IF(A(4,3) .LT. 0.0)WRITE(3,913)
       IF(A(5,3) .LT. 0.0)WRITE(3,914)
       IF(A(6,3) .LT. 0.0)WRITE(3,915)
       IF(A(7,3) .LT. 0.0)WRITE(3,916)
       IF(A(8,3) .LT. 0.0)WRITE(3,917)
C
       GO TO 103
C
C
C   TRICKLING FILTER TYPE PLANT
C
    90 READ(1,906)(A(I,1),I=1,7)
C
C           PRIMARY CLARIFIER
C      A(1,1)=TOTAL TANK VOLUME (1000 GAL)
C      A(2,1)=TOTAL SURFACE AREA (FT2)
C      A(3,1)=TOTAL WEIR LENGTH (FT)
C      A(4,1)=DESIGN FLOW RATE (MGD)
C      A(5,1)=DESIGN DETENTION PERIOD (HRS)
C      A(6,1)=DESIGN SURFACE SETTLING RATE (GPD/FT2)
C      A(7,1)=DESIGN WEIR OVERFLOW RATE (GPD/FT)
C
       WRITE(3,904)(UNIT(I,1),I=1,4)
       IF(A(1,1) .LT. 0.0)WRITE(3,910)
       IF(A(2,1) .LT. 0.0)WRITE(3,911)
       IF(A(3,1) .LT. 0.0)WRITE(3,912)
       IF(A(4,1) .LT. 0.0)WRITE(3,913)
       IF(A(5,1) .LT. 0.0)WRITE(3,914)
```

```
      IF(A(6,1) .LT. 0.0)WRITE(3,915)
      IF(A(7,1) .LT. 0.0)WRITE(3,916)
C
      READ(1,906)(A(I,2),I=1,5)
C
C         TRICKLING FILTER
C     A(1,2)=DESIGN FLOW RATE (MGD)
C     A(2,2)=DESIGN ORGANIC LOAD (LB BOD/ACRE-FT DAY)
C     A(3,2)=TOTAL FILTER VOLUME (ACRE-FT)
C     A(4,2)=TOTAL FILTER AREA (ACRES)
C     A(5,2)=TOTAL RECYCLE TO FILTER (MGD)
C
      WRITE(3,904)(UNIT(I,4),I=1,4)
      IF(A(1,2) .LT. 0.0)WRITE(3,940)
      IF(A(2,2) .LT. 0.0)WRITE(3,941)
      IF(A(3,2) .LT. 0.0)WRITE(3,942)
      IF(A(4,2) .LT. 0.0)WRITE(3,943)
      IF(A(5,2) .LT. 0.0)WRITE(3,944)
C
      READ(1,906)(A(I,3),I=1,8)
C
C         FINAL CLARIFIER
C     A(1,3)=TOTAL TANK VOLUME (1000 GAL)
C     A(2,3)=TOTAL SURFACE AREA (FT2)
C     A(3,3)=TOTAL WEIR LENGTH (FT)
C     A(4,3)=DESIGN FLOW RATE (MGD)
C     A(5,3)=DESIGN DETENTION PERIOD (HRS)
C     A(6,3)=DESIGN SURFACE SETTLING RATE (GPD/FT2)
C     A(7,3)=DESIGN WEIR OVERFLOW RATE (GPD/FT)
C     A(8,3)=DESIGN SOLIDS LOADING (LB SS/DAY/FT2)
C
      WRITE(3,904)(UNIT(I,3),I=1,4)
      IF(A(1,3) .LT. 0.0)WRITE(3,910)
      IF(A(2,3) .LT. 0.0)WRITE(3,911)
      IF(A(3,3) .LT. 0.0)WRITE(3,912)
      IF(A(4,3) .LT. 0.0)WRITE(3,913)
      IF(A(5,3) .LT. 0.0)WRITE(3,914)
      IF(A(6,3) .LT. 0.0)WRITE(3,915)
      IF(A(7,3) .LT. 0.0)WRITE(3,916)
      IF(A(8,3) .LT. 0.0)WRITE(3,917)
C
      GO TO 105
C
  103 CALL ACT(&200)
  105 CALL TFILT(&200)
  200 CONTINUE
      STOP
  901 FORMAT(I1,10A4)
  902 FORMAT(1H1///T41,50('*')/
     1  T41,'*          PLANT DESIGN AND OPERATION CHECK          *',
     2  /T41,50('*'))
  903 FORMAT(//T20,'DESIGN INFORMATION NOT AVAILABLE'/
     1  T20,32('*'))
  904 FORMAT(/T18,'**',4A4,'**')
  905 FORMAT(T52,4A4,'  TYPE PLANT')
  906 FORMAT(8F8.0)
  908 FORMAT(T46,10A4)
  910 FORMAT(T20,'TOTAL VOLUME')
```

```
  911 FORMAT(T20,'TOTAL SURFACE AREA')
  912 FORMAT(T20,'TOTAL WEIR LENGTH')
  913 FORMAT(T20,'FLOW RATE')
  914 FORMAT(T20,'DETENTION TIME')
  915 FORMAT(T20,'SURFACE SETTLING RATE')
  916 FORMAT(T20,'WEIR OVERFLOW RATE')
  917 FORMAT(T20,'SOLIDS LOADING')
  920 FORMAT(T20,'TOTAL TANK VOLUME')
  921 FORMAT(T20,'FLOW RATE')
  922 FORMAT(T20,'DETENTION PERIOD')
  923 FORMAT(T20,'ORGANIC LOADING')
  924 FORMAT(T20,'MLSS')
  925 FORMAT(T20,'NUMBER OF AERATORS OR COMPRESSORS')
  926 FORMAT(T20,'TOTAL AERATOR OR COMPRESSOR HORSEPOWER')
  940 FORMAT(T20,'FLOW RATE')
  941 FORMAT(T20,'ORGANIC LOADING')
  942 FORMAT(T20,'TOTAL FILTER VOLUME')
  943 FORMAT(T20,'TOTAL FILTER AREA')
  944 FORMAT(T20,'FILTER RECYCLE')
      END
```

```
      SUBROUTINE ACT(*)
      COMMON A(9,6),PLANT(10)
C
C  READ IN OPERATIONS DATA
C
      READ(1,901)(A(I,5),I=1,8)
C
C          GENERAL OPERATIONS
C     A(1,5)=PEAK FLOW (INFLUENT) (MGD)
C     A(2,5)=TOTAL DAILY FLOW (INFLUENT) (MG)
C     A(3,5)=BOD (INFLUENT) (MG/L)
C     A(4,5)=SUSPENDED SOLIDS (INFLUENT) (MG/L)
C     A(5,5)=BOD (EFFLUENT) (MG/L)
C     A(6,5)=SUSPENDED SOLIDS (EFFLUENT) (MG/L)
C     A(7,5)=AVERAGE TEMPERATURE (EFFLUENT) (DEG C)
C     A(8,5)=D.O. SATURATION IN AERATION BASIN (MG/L)
C
      WRITE(3,909)
      WRITE(3,910)
      IF(A(1,5) .LT. 0.0)WRITE(3,911)
      IF(A(2,5) .LT. 0.0)WRITE(3,912)
      IF(A(3,5) .LT. 0.0)WRITE(3,913)
      IF(A(4,5) .LT. 0.0)WRITE(3,914)
      IF(A(5,5) .LT. 0.0)WRITE(3,915)
      IF(A(6,5) .LT. 0.0)WRITE(3,916)
      IF(A(7,5) .LT. 0.0)WRITE(3,917)
      IF(A(8,5) .LT. 0.0)WRITE(3,918)
C
      READ(1,901)(A(I,6),I=1,9)
C
C          PROCESS OPERATIONS
C     A(1,6)=PRIMARY EFFLUENT BOD (MG/L)
C     A(2,6)=PRIMARY EFFLUENT SUSPENDED SOLIDS (MG/L)
C     A(3,6)=MIXED LIQUOR SUSPENDED SOLIDS (MG/L)
C     A(4,6)=VOLUME OF AIR DELIVERED (1000 FT3/DAY)
C     A(5,6)=HOURS OF OPERATION OF MECHANICAL AERATORS (HRS/DAY)
C     A(6,6)=RETURN SLUDGE VOLUME (MGD)
C     A(7,6)=RETURN SLUDGE SUSPENDED SOLIDS (MG/L)
C     A(8,6)=WASTE SLUDGE VOLUME (MGD)
C     A(9,6)=AVERAGE AERATION BASIN DISOLVED OXYGEN (MG/L)
C
      WRITE(3,920)
      IF(A(1,6) .LT. 0.0)WRITE(3,921)
      IF(A(2,6) .LT. 0.0)WRITE(3,922)
      IF(A(3,6) .LT. 0.0)WRITE(3,923)
      IF(A(4,6) .LT. 0.0)WRITE(3,924)
      IF(A(5,6) .LT. 0.0)WRITE(3,925)
      IF(A(6,6) .LT. 0.0)WRITE(3,926)
      IF(A(7,6) .LT. 0.0)WRITE(3,927)
      IF(A(8,6) .LT. 0.0)WRITE(3,928)
      IF(A(9,6) .LT. 0.0)WRITE(3,929)
C
      WRITE(3,902)
      WRITE(3,903)PLANT
      WRITE(3,904)
C
C  OPERATIONS AND DESIGN CHECK
C
```

```
C   PRIMARY CLARIFIER
C
C   DETENTION TIME
      IF(A(1,1) .LT. 0.)GO TO 101
      XA=A(1,1)/(A(2,5)*1.0E03/24.)
      XP=A(1,1)/(A(1,5)*1.0E03/24.)
      WRITE(3,930)A(5,1),XA,XP
C
C   SURFACE SETTLING RATE
  101 IF(A(2,1) .LT. 0.)GO TO 102
      XA=A(2,5)*1.0E06/A(2,1)
      XP=A(1,5)*1.0E06/A(2,1)
      WRITE(3,931)A(6,1),XA,XP
C
C   WEIR OVERFLOW RATE
  102 IF(A(3,1) .LT. 0.)GO TO 103
      XA=A(2,5)*1.0E06/A(3,1)
      XP=A(1,5)*1.0E06/A(3,1)
      WRITE(3,932)A(7,1),XA,XP
C
C   SOLIDS LOADING
  103 IF(A(4,5) .LT. 0.  .OR.  A(2,1) .LT. 0.)GO TO 104
      XA=A(4,5)*A(2,5)*8.34/A(2,1)
      [illegible]8.34/A(2,1)
C
C   EFFICIENCY
  104 IF(A(4,5) .LT. 0.  .OR.  A(2,6) .LT. 0.)GO TO 105
      EFF=((A(4,5)-A(2,6))/A(4,5))*100.
      WRITE(3,934)EFF
C
C   AERATION BASIN
C
C   DETENTION TIME
  105 IF(A(1,2) .LT. 0.)GO TO 106
      IF(A(6,6) .LT. 0.)GO TO 106
      XA=A(1,2)/((A(2,5)+A(6,6))*1.0E03)*24.
      XP=A(1,2)/((A(1,5)+A(6,6))*1.0E03)*24.
      WRITE(3,940)A(3,2),XA,XP
C
C   VOLUMETRIC LOADING
  106 IF(A(1,6) .LT. 0.  .OR.  A(1,2) .LT. 0.)GO TO 107
      XA=A(1,6)*A(2,5)*8.34/A(1,2)*7.481
      XP=A(1,6)*A(1,5)*8.34/A(1,2)*7.481
      WRITE(3,941)XA,XP
C
C   PROCESS LOADING INTENSITY
      IF(A(3,6) .LT. 0.)GO TO 107
      XA=A(1,6)*A(2,5)*8.34/(A(3,6)*A(1,2)*1.0E-03*8.34)
      XP=A(1,6)*A(1,5)*8.34/(A(3,6)*A(1,2)*1.0E-03*8.34)
      WRITE(3,942)XA,XP
C
C   AVERAGE SLUDGE AGE
  107 IF(A(3,6) .LT. 0. .OR. A(1,2) .LT. 0.)GO TO 108
      IF(A(8,6) .LT. 0. .OR. A(7,6) .LT. 0.)GO TO 108
      IF(A(6,5) .LT. 0.)GO TO 108
      XA=(A(3,6)*A(1,2)*1.0E-03*8.34)/((A(8,6)*1.E-06*A(7,6)*8.34)+
     1  ((A(2,5)-A(8,6)*1.E-06)*A(6,5)*8.34))
```

```
      WRITE(3,943)XA
C
C  DIFFUSED AERATION
C  VOLUMETRIC AIR SUPPLY
  108 IF(A(4,6) .LT. 0.0) GO TO 110
      IF(A(1,2) .LT. 0.)GO TO 109
      XA=A(4,6)*1000.*7.48052/(A(1,2)*24.*60.)
      WRITE(3,944)XA
C
C  ORGANIC AIR SUPPLY
  109 IF(A(1,6) .LT. 0.)GO TO 112
      XA=A(4,6)*1000./(A(1,6)*A(2,5)*8.34)
      WRITE(3,945)XA
      GO TO 112
C
C  MECHANICAL AERATION
C  VOLUMETRIC POWER SUPPLY
  110 IF(A(7,2) .LT. 0.0  .OR.  A(1,2) .LT. 0.0)GO TO 112
      XA=A(7,2)/A(1,2)*7.48052
      WRITE(3,946)XA
C
C ORGANIC OXYGEN SUPPLY
  111 IF(A(9,6) .LT. 0. .OR. A(1,6) .LT. 0.)GO TO 112
      IF(A(5,6) .LT. 0. .OR. A(8,5) .LT. 0.)GO TO 112
      ON=2.5*((A(8,5)-A(9,6))/9.17)*1.024**(A(7,5)-20.)*0.8
      XA=ON*A(7,2)*A(5,6)/(A(1,6)*A(2,5)*8.34)
      WRITE(3,947)XA
C
C  EFFICIENCY
  112 IF(A(1,6) .LT. 0. .OR. A(5,5) .LT. 0.)GO TO 113
      EFF=(A(1,6)-A(5,5))/A(1,6)*100.
      WRITE(3,948)EFF
C
C  SECONDARY CLARIFIER
C
C  DETENTION TIME
  113 IF(A(1,3) .LT. 0.)GO TO 114
      IF(A(6,6) .LT. 0.)GO TO 117
      XA=A(1,3)/((A(2,5)+A(6,6))*1.0E03)*24.
      XP=A(1,3)/((A(1,5)+A(6,6))*1.0E03)*24.
      WRITE(3,950)A(5,3),XA,XP
C
C  SURFACE SETTLING RATE
  114 IF(A(2,3) .LT. 0.)GO TO 115
      XA=((A(2,5)+A(6,6))*1.0E06)/A(2,3)
      XP=((A(1,5)+A(6,6))*1.0E06)/A(2,3)
      WRITE(3,951)A(6,3),XA,XP
C
C  WEIR OVERFLOW RATE
  115 IF(A(3,3) .LT. 0.)GO TO 116
      XA=(A(2,5)+A(6,6))*1.0E06/A(3,3)
      XP=(A(1,5)+A(6,6))*1.0E06/A(3,3)
      WRITE(3,952)A(7,3),XA,XP
C
C  SOLIDS LOADING
  116 IF(A(2,3) .LT. 0.)GO TO 117
      IF(A(3,6) .LT. 0.)GO TO 118
      XA=A(3,6)*(A(2,5)+A(6,6))*8.34/A(2,3)
```

```
      XP=A(3,6)*(A(1,5)+A(6,6))*8.34/A(2,3)
      WRITE(3,953)A(8,3),XA,XP
C
C  EFFICIENCY
  117 IF(A(6,5) .LT. 0.)GO TO 118
      EFF=(A(3,6)-A(6,5))/A(3,6)*100.
      WRITE(3,954)EFF
C
C  PLANT BOD EFFICIENCY
  118 IF(A(3,5) .LT. 0. .OR. A(5,5) .LT. 0.)GO TO 119
      E=(A(3,5)-A(5,5))/A(3,5)*100.
      WRITE(3,960)E
C
C  PLANT SUSPENDED SOLIDS EFFICIENCY
  119 IF(A(4,5) .LT. 0. .OR. A(6,5) .LT. 0.)GO TO 120
      E=(A(4,5)-A(6,5))/A(4,5)*100.
      WRITE(3,961)E
C
  120 CONTINUE
      RETURN1
  901 FORMAT(10F8.0)
  902 FORMAT(1H1///,T41,50('*')/
     1  T41,'*          PLANT DESIGN AND OPERATION CHECK          *',
     2  /T41,50('*'))
  903 FORMAT(T46,10A4)
  904 FORMAT(//T30,'PARAMETER',T74,'DESIGN',T88,'AVERAGE',T106,'PEAK'/
     1          T30,'*********',T74,'******',T88,'*******',T106,'****'/)
  909 FORMAT(/T20,'OPERATIONS INFORMATION NOT AVAILABLE',
     1  /T20,36('*'))
  910 FORMAT(/T18,'** GENERAL OPERATIONS **')
  911 FORMAT(T20,'PEAK FLOW')
  912 FORMAT(T20,'TOTAL DAILY FLOW')
  913 FORMAT(T20,'AVERAGE INFLUENT BOD')
  914 FORMAT(T20,'AVERAGE INFLUENT SUSPENDED SOLIDS')
  915 FORMAT(T20,'AVERAGE EFFLUENT BOD')
  916 FORMAT(T20,'AVERAGE EFFLUENT SUSPENDED SOLIDS')
  917 FORMAT(T20,'AVERAGE EFFLUENT TEMPERATURE')
  918 FORMAT(T20,'D.O. SATURATION IN AERATION BASIN')
  920 FORMAT(/T18,'** PROCESS OPERATIONS **')
  921 FORMAT(T20,'PRIMARY EFFLUENT BOD')
  922 FORMAT(T20,'PRIMARY EFFLUENT SUSPENDED SOLIDS')
  923 FORMAT(T20,'MIXED LIQUOR SUSPENDED SOLIDS')
  924 FORMAT(T20,'VOLUME OF AIR DELIVERED')
  925 FORMAT(T20,'HOURS OF OPERATION OF MECHANICAL AERATORS')
  926 FORMAT(T20,'RETURN SLUDGE VOLUME')
  927 FORMAT(T20,'RETURN SLUDGE SUSPENDED SOLIDS')
  928 FORMAT(T20,'WASTE SLUDGE VOLUME')
  929 FORMAT(T20,'AVERAGE AERATION BASIN DISOLVED OXYGEN')
  930 FORMAT(/T10,'PRIMARY CLARIFIER DETENTION TIME (HRS)',T70,F10.3,T85
     1  ,F10.3,T100,F10.3)
  931 FORMAT(/T10,'PRIMARY CLARIFIER SURFACE SETTLING RATE (GPD/FT2)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  932 FORMAT(/T10,'PRIMARY CLARIFIER WEIR OVERFLOW RATE (GPD/FT)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  933 FORMAT(/T10,'PRIMARY CLARIFIER SOLIDS LOADING RATE (LB SS/FT2',
     1  '-DAY)',T85,F10.3,T100,F10.3)
  934 FORMAT(/T10,'PRIMARY CLARIFIER SOLIDS REMOVAL EFFICIENCY',
     1  T120,F5.1,' %')
```

```
  940 FORMAT(/T10,'AERATION BASIN DETENTION TIME (HRS)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  941 FORMAT(/T10,'AERATION BASIN VOLUMETRIC LOADING ',
     1  '(LB BOD/1000 FT3-DAY)',T85,F10.3,T100,F10.3)
  942 FORMAT(/T10,'PROCESS LOADING INTENSITY (LB BOD/LB MLSS-DAY)',
     1  T85,F10.3,T100,F10.3)
  943 FORMAT(/T10,'AVERAGE SLUDGE AGE (DAYS)',T85,F10.3)
  944 FORMAT(/T10,'VOLUMETRIC AIR SUPPLY (CFM/1000 FT3)'
     1  ,T85,F10.3)
  945 FORMAT(/T10,'ORGANIC AIR SUPPLY (FT3/LB BOD)',
     1  T85,F10.3)
  946 FORMAT(/T10,'VOLUMETRIC POWER SUPPLIED (HP/1000 FT3)',
     1  T85,F10.3)
  947 FORMAT(/T10,'ORGANIC OXYGEN SUPPLY (LB O2/LB BOD)',
     1  T85,F10.3)
  948 FORMAT(/T10,'AERATION BASIN BOD REMOVAL EFFICIENCY',T120,F5.1,
     1  ' %')
  950 FORMAT(/T10,'SECONDARY CLARIFIER DETENTION TIME (HRS)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  951 FORMAT(/T10,'SECONDARY CLARIFIER SURFACE SETTLING RATE (GPD/',
     1  'FT2)',T70,F10.3,T85,F10.3,T100,F10.3)
  952 FORMAT(/T10,'SECONDARY CLARIFIER WEIR OVERFLOW RATE (GPD/FT)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  953 FORMAT(/T10,'SECONDARY CLARIFIER SOLIDS LOADING RATE (LB SS/FT2',
     1  '-DAY)',T70,F10.3,T85,F10.3,T100,F10.3)
  954 FORMAT(/T10,'SECONDARY CLARIFIER SOLIDS REMOVAL EFFICIENCY',
     1  T120,F5.1,' %')
  960 FORMAT(/T10,'OVERALL PLANT BOD REMOVAL EFFICIENCY',
     1  T120,F5.1,' %')
  961 FORMAT(/T10,'OVERALL PLANT SOLIDS REMOVAL EFFICIENCY',
     1  T120,F5.1,' %')
      END
```

```
      SUBROUTINE TFILT(*)
      COMMON A(9,6),PLANT(10)
C
C  READ IN OPERATIONS DATA
C
      READ(1,901)(A(I,5),I=1,6)
C
C          GENERAL OPERATIONS
C     A(1,1)=PEAK FLOW (INFLUENT) (MGD)
C     A(2,5)=TOTAL DAILY FLOW (INFLUENT) (MG)
C     A(3,5)=BOD (INFLUENT) (MG/L)
C     A(4,5)=SUSPENDED SOLIDS (INFLUENT) (MG/L)
C     A(5,5)=BOD (EFFLUENT) (MG/L)
C     A(6,5)=SUSPENDED SOLIDS (EFFLUENT) (MG/L)
C
      WRITE(3,909)
      WRITE(3,910)
      IF(A(1,5) .LT. 0.0)WRITE(3,911)
      IF(A(2,5) .LT. 0.0)WRITE(3,912)
      IF(A(3,5) .LT. 0.0)WRITE(3,913)
      IF(A(4,5) .LT. 0.0)WRITE(3,914)
      IF(A(5,5) .LT. 0.0)WRITE(3,915)
      IF(A(6,5) .LT. 0.0)WRITE(3,916)
C
      READ(1,901)(A(I,6),I=1,8)
C
C     PROCESS OPERATIONS
C
C     A(1,6)=PRIMARY EFFLUENT BOD (MG/L)
C     A(2,6)=PRIMARY EFFLUENT SUSPENDED SOLIDS (MG/L)
C     A(3,6)=FILTER EFFLUENT BOD (MG/L)
C     A(4,6)=FILTER EFFLUENT SUSPENDED SOLIDS (MG/L)
C     A(5,6)=RECYCLE TO FILTER (MGD)
C     A(6,6)=RECYCLE FROM FILTER (MGD)
C     A(7,6)=RECYCLE FROM SECONDARY CLARIFIER (MGD)
C
      WRITE(3,920)
      IF(A(1,6) .LT. 0.0)WRITE(3,921)
      IF(A(2,6) .LT. 0.0)WRITE(3,922)
      IF(A(3,6) .LT. 0.0)WRITE(3,923)
      IF(A(4,6) .LT. 0.0)WRITE(3,924)
      IF(A(5,6) .LT. 0.0)WRITE(3,925)
      IF(A(6,6) .LT. 0.0)WRITE(3,926)
      IF(A(7,6) .LT. 0.0)WRITE(3,927)
C
      WRITE(3,902)
      WRITE(3,903)PLANT
      WRITE(3,904)
C
C  OPERATIONS AND DESIGN CHECK
C
C  PRIMARY CLARIFIER
C
C  DETENTION TIME
      IF(A(1,1) .LT. 0.)GO TO 100
      XA=A(1,1)/(A(2,5)*1.0E03/24.)
      XP=A(1,1)/(A(1,5)*1.0E03/24.)
      WRITE(3,930)A(5,1),XA,XP
```

```
C
C  SURFACE SETTLING RATE
  100 IF(A(2,1) .LT. 0.)GO TO 101
      XA=A(2,5)*1.0E06/A(2,1)
      XP=A(1,5)*1.0E06/A(2,1)
      WRITE(3,931)A(6,1),XA,XP
C
C  WEIR OVERFLOW RATE
  101 IF(A(3,1) .LT. 0.)GO TO 102
      XA=A(2,5)*1.0E06/A(3,1)
      XP=A(1,5)*1.0E06/A(3,1)
      WRITE(3,932)A(7,1),XA,XP
C
C  SOLIDS LOADING
  102 IF(A(4,5) .LT. 0. .OR. A(2,1) .LT. 0.)GO TO 103
      XA=A(4,5)*A(2,5)*8.34/A(2,1)
      XP=A(4,5)*A(1,5)*8.34/A(2,1)
      WRITE(3,933)XA,XP
C
C  EFFICIENCY
  103 IF(A(4,5) .LT. 0. .OR. A(2,6) .LT. 0.)GO TO 104
      EFF=((A(4,5)-A(2,6))/A(4,5))*100.
      WRITE(3,934)EFF
C
C  TRICKLING FILTER
C
C  HYDRAULIC LOADING
  104 IF(A(4,2) .LT. 0.)GO TO 106
      IF(A(5,6) .LT. 0.)GO TO 106
      XA=(A(2,5)+A(5,6))/A(4,2)
      XP=(A(1,5)+A(5,6))/A(4,2)
  105 XD=(A(1,2)+A(5,2))/A(4,2)
      IF(A(1,2) .LT. 0. .OR. A(5,2) .LT. 0.)XD=-1.
      WRITE(3,940)XD,XA,XP
C
C  ORGANIC LOADING
  106 IF(A(1,6) .LT. 0. .OR. A(3,2) .LT. 0.)GO TO 107
      XA=(A(2,5)*A(1,6)*8.34)/A(3,2)
      XP=(A(1,5)*A(1,6)*8.34)/A(3,2)
      WRITE(3,941)A(2,2),XA,XP
C
C  RECIRCULATION RATIO
  107 IF(A(5,6) .LT. 0.)GO TO 108
      XA=A(5,6)/A(2,5)
      XP=A(5,6)/A(1,5)
  108 XD=A(5,2)/A(1,2)
      IF(A(5,2) .LT. 0. .OR. A(1,2) .LT. 0.)XD=-1.
      WRITE(3,942)XD,XA,XP
C
C  EFFICIENCY
  109 IF(A(1,6) .LT. 0. .OR. A(5,5) .LT. 0.)GO TO 110
      E=(A(1,6)-A(5,5))/A(1,6)*100.
      WRITE(3,943)E
C
C  SECONDARY CLARIFIER
C
C  DETENTION TIME
  110 IF(A(1,3) .LT. 0.)GO TO 111
```

```
      IF(A(5,6) .LT. 0. .OR. A(6,6) .LT. 0.)GO TO 114
      XA=A(1,3)/((A(2,5)+A(5,6)-A(6,6))*1.0E03)*24.
      XP=A(1,3)/((A(1,5)+A(5,6)-A(6,6))*1.0E03)*24.
      WRITE(3,950)A(5,3),XA,XP
C
C  SURFACE SETTLING RATE
  111 IF(A(2,3) .LT. 0.)GO TO 112
      XA=(A(2,5)+A(5,6)-A(6,6))*1.0E06/A(2,3)
      XP=(A(1,5)+A(5,6)-A(6,6))*1.0E06/A(2,3)
      WRITE(3,951)A(6,3),XA,XP
C
C  WEIR OVERFLOW RATE
  112 IF(A(3,3) .LT. 0.)GO TO 113
      XA=(A(2,5)+A(5,6)-A(6,6))*1.0E06/A(3,3)
      XP=(A(1,5)+A(5,6)-A(6,6))*1.0E06/A(3,3)
      WRITE(3,952)A(7,3),XA,XP
C
C  SOLIDS LOADING
  113 IF(A(4,6) .LT. 0.)GO TO 115
      IF(A(5,6) .LT. 0. .OR. A(6,6) .LT. 0.)GO TO 114
      IF(A(2,3) .LT. 0.)GO TO 114
      XA=(A(2,5)+A(5,6)-A(6,6))*A(4,6)*8.34/A(2,3)
      XP=(A(1,5)+A(5,6)-A(6,6))*A(4,6)*8.34/A(2,3)
      WRITE(3,953)A(8,3),XA,XP
C
C  EFFICIENCY
  114 IF(A(6,5) .LT. 0.)GO TO 115
      E=(A(4,6)-A(6,5))/A(4,6)*100.
      WRITE(3,954)E
C
C  PLANT BOD EFFICIENCY
  115 IF(A(3,5) .LT. 0. .OR. A(5,5) .LT. 0.)GO TO 116
      E=(A(3,5)-A(5,5))/A(3,5)*100.
      WRITE(3,960)E
C
C  PLANT SUSPENDED SOLIDS EFFICIENCY
  116 IF(A(4,5) .LT. 0. .OR. A(6,5) .LT. 0.)GO TO 117
      E=(A(4,5)-A(6,5))/A(4,5)*100.
      WRITE(3,961)E
C
  117 CONTINUE
      RETURN1
  901 FORMAT(9F8.0)
  902 FORMAT(1H1///T41,50('*')/
     1  T41,'*         PLANT DESIGN AND OPERATION CHECK        *',
     2  /T41,50('*'))
  903 FORMAT(T46,10A4)
  904 FORMAT(//T30,'PARAMETER',T74,'DESIGN',T88,'AVERAGE',T106,'PEAK'/
     1          T30,'*********',T74,'******',T88,'*******',T106,'****'/)
  909 FORMAT(/T20,'OPERATIONS INFORMATION NOT AVAILABLE',
     1  /T20,36('*'))
  910 FORMAT(/T18,'** GENERAL OPERATIONS **')
  911 FORMAT(T20,'PEAK FLOW')
  912 FORMAT(T20,'TOTAL DAILY FLOW')
  913 FORMAT(T20,'AVERAGE INFLUENT BOD')
  914 FORMAT(T20,'AVERAGE INFLUENT SUSPENDED SOLIDS')
  915 FORMAT(T20,'AVERAGE EFFLUENT BOD')
  916 FORMAT(T20,'AVERAGE EFFLUENT SUSPENDED SOLIDS')
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  920 FORMAT(/T18,'** PROCESS OPERATIONS **')
  921 FORMAT(T20,'PRIMARY EFFLUENT BOD')
  922 FORMAT(T20,'PRIMARY EFFLUENT SUSPENDED SOLIDS')
  923 FORMAT(T20,'FILTER EFFLUENT BOD')
  924 FORMAT(T20,'FILTER EFFLUENT SUSPENDED SOLIDS')
  925 FORMAT(T20,'RECYCLE TO FILTER')
  926 FORMAT(T20,'RECYCLE FROM FILTER')
  927 FORMAT(T20,'RECYCLE FROM SECONDARY CLARIFIER')
  930 FORMAT(/T10,'PRIMARY CLARIFIER DETENTION TIME (HRS)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  931 FORMAT(/T10,'PRIMARY CLARIFIER SURFACE SETTLING RATE (GPD/FT2)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  932 FORMAT(/T10,'PRIMARY CLARIFIER WEIR OVERFLOW RATE (GPD/FT)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  933 FORMAT(/T10,'PRIMARY CLARIFIER SOLIDS LOADING RATE (LB SS/FT2'
     1  ,'-DAY)',T85,F10.3,T100,F10.3)
  934 FORMAT(/T10,'PRIMARY CLARIFIER SOLIDS REMOVAL EFFICIENCY',
     1  T120,F5.1,' %')
  940 FORMAT(/T10,'TRICKLING FILTER HYDRAULIC LOADING (MGAD)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  941 FORMAT(/T10,'TRICKLING FILTER ORGANIC LOADING (LB BOD/ACRE-'
     1  ,'FT-DAY)',T70,F10.3,T85,F10.3,T100,F10.3)
  942 FORMAT(/T10,'FILTER RECIRCULATION RATIO (RECIRCULATION/INFLUENT)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  943 FORMAT(/T10,'FILTER BOD REMOVAL EFFICIENCY',
     1  T120,F5.1,' %')
  950 FORMAT(/T10,'SECONDARY CLARIFIER DETENTION TIME (HRS)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  951 FORMAT(/T10,'SECONDARY CLARIFIER SURFACE SETTLING RATE (GPD/FT2)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  952  FORMAT(/T10,'SECONDARY CLARIFIER WEIR OVERFLOW RATE (GPD/FT)',
     1  T70,F10.3,T85,F10.3,T100,F10.3)
  953 FORMAT (/T10,'SECONDARY CLARIFIER SOLIDS LOADING RATE (LB SS/FT2',
     1  '-DAY)',T70,F10.3,T85,F10.3,T100,F10.3)
  954 FORMAT(/T10,'SECONDARY CLARIFIER SOLIDS REMOVAL EFFICIENCY',
     1  T120,F5.1,' %')
  960 FORMAT(/T10,'OVERALL PLANT BOD REMOVAL EFFICIENCY',
     1  T120,F5.1,' %')
  961 FORMAT(/T10,'OVERALL PLANT SOLIDS REMOVAL EFFICIENCY',
     1  T120,F5.1,' %')
      END
```

APPENDIX D

Output From Indicator Model Program

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**************************************************
*        PLANT DESIGN AND OPERATION CHECK        *
**************************************************
                    FORT ORD, CA
             TRICKLING FILTER  TYPE PLANT

  DESIGN INFORMATION NOT AVAILABLE
  ********************************

**PRIMARY SETTLING**
  TOTAL WEIR LENGTH
  WEIR OVERFLOW RATE

**TRICKLING FILTER**
  FILTER RECYCLE

**FINAL CLARIFIER **
  SOLIDS LOADING

  OPERATIONS INFORMATION NOT AVAILABLE
  ************************************

** GENERAL OPERATIONS **

** PROCESS OPERATIONS **
  FILTER EFFLUENT SUSPENDED SOLIDS
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PLANT DESIGN AND OPERATION CHECK

FORT ORD, CA

PARAMETER	DESIGN	AVERAGE	PEAK	
PRIMARY CLARIFIER DETENTION TIME (HRS)	2.500	5.280	3.314	
PRIMARY CLARIFIER SURFACE SETTLING RATE (GPD/FT2)	701.670	340.000	541.667	
PRIMARY CLARIFIER SOLIDS LOADING RATE (LB SS/FT2-DAY)		1.009	1.608	
PRIMARY CLARIFIER SOLIDS REMOVAL EFFICIENCY				19.1 %
TRICKLING FILTER HYDRAULIC LOADING (MGAD)	-1.000	7.446	9.607	
TRICKLING FILTER ORGANIC LOADING (LB BOD/ACRE-FT-DAY)	1973.300	981.553	1563.750	
FILTER RECIRCULATION RATIO (RECIRCULATION/INFLUENT)	-1.000	1.044	0.655	
FILTER BOD REMOVAL EFFICIENCY				61.0 %
SECONDARY CLARIFIER DETENTION TIME (HRS)	1.700	3.498	2.196	
SECONDARY CLARIFIER SURFACE SETTLING RATE (GPD/FT2)	950.000	461.762	735.650	
SECONDARY CLARIFIER WEIR OVERFLOW RATE (GPD/FT)	6130.000	2970.296	4732.090	
OVERALL PLANT BOD REMOVAL EFFICIENCY				75.7 %
OVERALL PLANT SOLIDS REMOVAL EFFICIENCY				69.1 %